IMAGE PROCESSING ALGORITHMS FOR ACCURATE POSITIONING OF LATHE TOOL

SHORT SYNOPSIS

Submitted in partial fulfillment of the requirement of the degree of

DOCTOR OF PHILOSOPHY

by

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2023

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DECLARATION BY THE SCHOLAR

I hereby declare that the short synopsis entitled **"Image Processing Algorithms for Accurate Positioning of Lathe Tool"** being submitted in partial fulfillment of the requirement for the degree of Doctor of Philosophy in the Department of Electronics and Communication Engineering under the School of Engineering of Manav Rachna University, Faridabad during the academic year 2022-23.

It is the work that is expected to be carried out under the supervision of Dr. Charu Pathak and co-supervision of Dr. Shruti Vashist.

Further, it is declared that the short synopsis is within the plagiarism limit and copy of the same is attached as per the University norms.

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ABSTRACT

This research proposal aims to investigate the use of image processing techniques to improve the accuracy of tool positioning in mechanical automation and smart manufacturing. The precise positioning of tools is critical for the production of tiny parts, where accuracy at the micrometer level is crucial. The proposed study will focus on the estimation of the position of a lathe tool using image processing in situations where the workpiece is stationary, with a goal of reducing the positioning inaccuracies of the lathe tool by analyzing the tool position error and tool travel distance.

The proposed research will address the limitations of traditional contact methods for detecting the travel distance of tools associated with piezoelectric motors, which suffer from uncertain sensor accuracy, error accumulation, and data drifts and noise. By exploring the use of image processing techniques, the study aims to achieve accurate tool positioning at the micrometer level, which will increase the efficiency and accuracy of mechanical manufacturing processes and robotics.

The study will utilize various image processing methods to enhance the results and improve overall performance. The findings of this research will contribute to the development of fast, cost-effective, and accurate tool positioning systems that can operate directly on high-resolution images of the tool. The proposed study will make a significant contribution towards the enhancement of tool positioning in mechanical manufacturing processes and robotics, with potential applications in various industries.

Key words: Lathe tool, image processing, edge detection, visual tool positioning, thresholding

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1. Introduction

1.1 Background

Numerous fields, including manufacturing, medicine, and several applications in mechanical engineering, benefit greatly from precise and accurate tool positioning. Such applications can call for micrometer-level precision. It also applies to measurements of tool dimensions, such as those for cutting, milling, and lathe tools, which degrade over time. Utilizing micro level sensors is crucial in today's technologically advanced world to check accurately the position and dimensions of equipment. Since a few years ago, a variety of tool placement techniques have been used, including co-ordinate measuring machines, offset measurement techniques, atomic force microscopes, and laser interferometers. Both dynamic and static tool positioning have an impact on the process's outcomes. Dynamic data are crucial to understand the contouring behavior at high traversal speeds. In these situations, error measurements are utilized to set the settings of a CNC machine's control loop and a position feedback system. These measurements can be used to improve a machine's kv factor, reversal peaks, and other behavioral factors. The static location of the linear and rotary axes has an impact on the geometric accuracy and thermal behavior of a machine. Here, a framework based on image processing has been developed for the real-time positioning and dimensioning system for the verification of accurate tool positioning in micrometer range. Using a tool's image to position it and calculating its precise dimensions has many uses because the same can increase cutting accuracy. The precision of a tool can be impacted by its wear and tear as well as its location. Researchers have implemented various strategies for the estimation process of tool wear and tear. By using optimization approaches, it is possible to estimate the imaging tool's wear and tear and place it with an accuracy of up to a few micrometers. Machine vision techniques are expanding steadily in biomedical applications because of the importance of imaging, which includes X-rays, MRI, FMRI, CT scans, etc. When it comes to numerous mechanical engineering applications, such as cutting tool positioning, precision and accuracy are of utmost importance. The need for extremely precise measurement of miniature microparts in mechanical and optical systems is growing daily. The positioning and measurement of the tool with extreme precision is a crucial step in the development of micro-machines. Edge detection algorithms have been used to locate an object's borders in each image.

1.2 Significance of the Topic

This research aims to address the limitations and challenges associated with conventional tool positioning methods such as co-ordinate measuring machine, offset measurement method, atomic force microscope, laser interferometers, etc. These methods have limited accuracy due to drifts and noise in sensors. The high error rate in the contact method of measuring distance makes it inadequate for precise measurements.

To overcome these challenges, a new non-contact technique based on image processing is proposed. This technique utilizes various image processing methods to enhance the accuracy of the tool position and to eliminate the errors associated with the conventional methods. The proposed technique has the potential to be used as a positioning aid in various applications, where precise tool positioning is crucial for successful outcomes.

2. Literature Review

Machine vision-based tool positioning and verification is a crucial area of research since it has applications in a variety of industrial, aerospace, medical, and mechanical operations processes [1]–[4]. Scanner electron microscopes, coordinate measuring machines, linear encoders, actuators, laser interferometers, atomic force microscopes, and other tools have all been used in the past to measure and confirm tool location [5]–[13]. An edge is helpful in accurate positioning because thresholding distinguishes and isolates a plane, an object, or an aspect from other items [14]. In automated manufacturing applications , robotic surgeries etc. temperatures and tensions within the cutting zone constantly fluctuate as a result of the cutting tool's wear during machining [15]. As an example, to mention in one of the medical field applications, a robot for performing eye surgery was developed, as this required very high accuracy [16]. In any of such applications, tools required has to be replaced at a particular instant of time. If tools are replaced too frequently and too early, machine idle time will increase, which will increase the cost of materials and output. But if a replacement is done too late, it could lead to poor quality or even unanticipated machine downtime [17]. Low processing costs, flexible manufacturing, high levels of machining precision and efficiency, and a great adaptability for processing complex micro-miniature parts are only a few advantages of micro-cutting technology. Because of the small size of the tools and components used in micro-machining processes and the need for exceptional machining accuracy, tool wear has a significant impact on processing quality [18]. Thus, various methods

have been developed to measure the position and dimensions of tools up to accuracy of micrometers. Broadly the methods are divided into two main categories namely direct approach and indirect approach. In addition to these, there are various other applications where the position and dimensions of tools need to be highly accurate. The states of tool wear are often measured indirectly using the main shaft current, acoustic emission, characteristics of machined surfaces, and surface quality. To make direct observations on the degree of tool wear, direct tests often use machine vision or an optical microscope [18][19]. Segmenting an image is one of the most important steps in computer vision, image processing, and image recognition. Extraction of the desired area is based on a set of standards that separate an input image into a number of related images belonging to the same category [20]. The level of accuracy required in all of the mentioned applications is at the micron scale. The contact method of measuring the travel distance of a piezoelectric motor's tool has a number of limitations of its own. The degree of accuracy or error in the case of sensors is not guaranteed, and the more flaws there are, the more quickly drifts and noise render the data unusable [8]. The objective of the study here is to attain proper tool positioning at the mm level, and image processing has been chosen as the method of achieving this objective due to its potential to enhance accuracy.

Numerous researchers have pursued this line of research and used a machine vision-based technique to quantify tool wear. Lai and Fang presented a hybrid image using an alignment method they called the Fast Localization System using the FLASH (Advanced Search Hierarchy) approach, which compares images and looks for discrepancies in the localization of patterns [21]. A two-step programmed arrangement method created by Kim et al. for detecting machine coordinate deviations from standard placements based on geometric relationships and evaluation data [22]. Nian and Tarng developed a method for a three-axis auto-alignment system using inspection based on vision that connects the input-output system with feedback [23]. Applications and system designs for industrial machine vision are discussed by Asadpour and Golnabi [24]. Some authors have used methods like the Algorithm Horn Schunck, for Motion Detection of Real-Time Human, and CMM Embedded System to detect movement [25]–[27]. The wear on the flanks can be measured using a machine vision technique developed by Kurada et al. For highlighting wear areas, they employed picture threshold [28][29]. Regarding accuracy and precision, cutting tool position is a key factor in many mechanical engineering applications. As mechanical and optical products continue to get smaller, the demand for incredibly accurate

dimensions measurements of microparts is rising. Making micro-machines requires precise placement and measurement of ultra-precise equipment [30]–[33]. Using image processing as a tool and segmentation approaches based on various thresholding techniques, we perform visual positioning in our study in order to achieve the most precise tool positioning at the micrometer level. Identifying the sharp edges precisely in images is of great importance in placing the cutting tool at the exact position [34][35]. These methods can be used for accurate positioning in robotic surgery on milling machines, lathe machines, and other machines with machine positional accuracy [36]–[38]. Accurate measurement of micropart dimensions is crucial as the technological advancements have made it possible to miniaturize medical products [39]–[42]. When executing a milling operation, for instance, a tool used to make everyday items may wear out over time [43]–[45]. The changes in tool dimensions reduce the efficiency of tools. Therefore, the tool should be promptly replaced after the tool's condition has been assessed. The use of sensors like microphones, accelerometers, and other devices makes indirect tool conditioning monitoring expensive. Through the use of MATLAB software's image processing package, direct tool conditioning monitoring can be carried out [46][47]. Images recorded by cameras are processed in a computer using an image processing algorithm [30]. Today, many computer vision systems still frequently use canny edge detection as a pre-processing phase. It is a straightforward yet effective technique [48][49].

3. Justification of the Study

As evident from the literature survey, contact methods for measuring the distance travelled by a precision DC motor-attached tool can have limitations in accuracy and precision due to sensor drifts and noise. In applications where precision and accuracy are important, non-contact methods for distance measurement can be more reliable and effective.

Machine vision and image processing using MATLAB can be employed to develop a non-contact method for measuring distance travelled by a precision DC motor-attached tool. The approach involves comparing the travelled distance to a predetermined target distance, allowing for the identification of errors and enabling automatic alignment of the tool. In the biomedical field, where small movements can have significant impacts, such non-contact methods can prove to be crucial.

This technology finds broad applications in the biomedical field, where it can serve as positioning devices and be employed in robotic surgical tools. Accurately and reliably measuring

distances without contact can significantly enhance the precision and effectiveness of surgical tools, thereby improving patient outcomes. Indeed, the applications of non-contact distance measurement using machine vision and image processing extend beyond the biomedical field. In smart manufacturing and mechanical automation, where precision and accuracy are critical, non-contact methods of distance measurement can be highly effective.

4. Objectives of the Study

1. To estimate the position and size of a lathe tool using various image processing techniques.
2. To estimate the errors in position of moving lathe tool, which can be used as a feedback for an auto alignment system.

5. Methodology and Research Plan

To perform the experiment and testing of the proposed algorithms, an experimental set up of moving lathe tool is required. The set up has an imaging facility too. The experimental setup requires a PC, Motion card, Piezoelectric motor, Vibration isolation table, CCD camera, IEEE 1394b FireWire Controller Card, and MATLAB software. It includes a moving Lathe tool and a stationary work piece. This system can be used to capture the images of the lathe tool at different positions in steps of 1 mm. The methodology involves following steps:

1. Calibration of the imaging system: The imaging system of the setup is first calibrated using standard calibration grid.
2. Development and implementation of algorithms as defined in objectives using various edge detection, segmentation, thresholding techniques.
3. Testing of algorithms on realistic images of lathe tools.
4. Comparison of the results from various algorithms to identify the pros and cons of each edge detection techniques.

Research Plan

The work is divided into four main stages broadly listed below.

Stage 1: Literature review and research objective finalization.

Stage 2: Implementation of existing segmentation techniques-based thresholding algorithms suited for visual positioning.

Stage 3: Development of algorithms to achieve the research objectives.

Stage 4: Implementation and testing of developed algorithms on images of lathe tools.

Stage 5: Collating the results and thesis writing.

6. Expected outcome of the research

With the advent of automated technology in manufacturing, healthcare, high accuracy machines are required. As an outcome of this research, more accurate automated systems can be developed to detect and warn the inaccurate positioning and size of lathe tools. These would be image based systems which are contactless and economic.

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File name: ROCESSING_ALGORITHMS_FOR_ACCURATE_POSITIONING_OF_LATHE_TOOL.docx (122.71K)
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Character count: 21899

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